

# Monitoring of California Levees with Airborne Remote Sensing



Sacramento Delta / false color UAVSAR POLSAR image / 7 m resolution

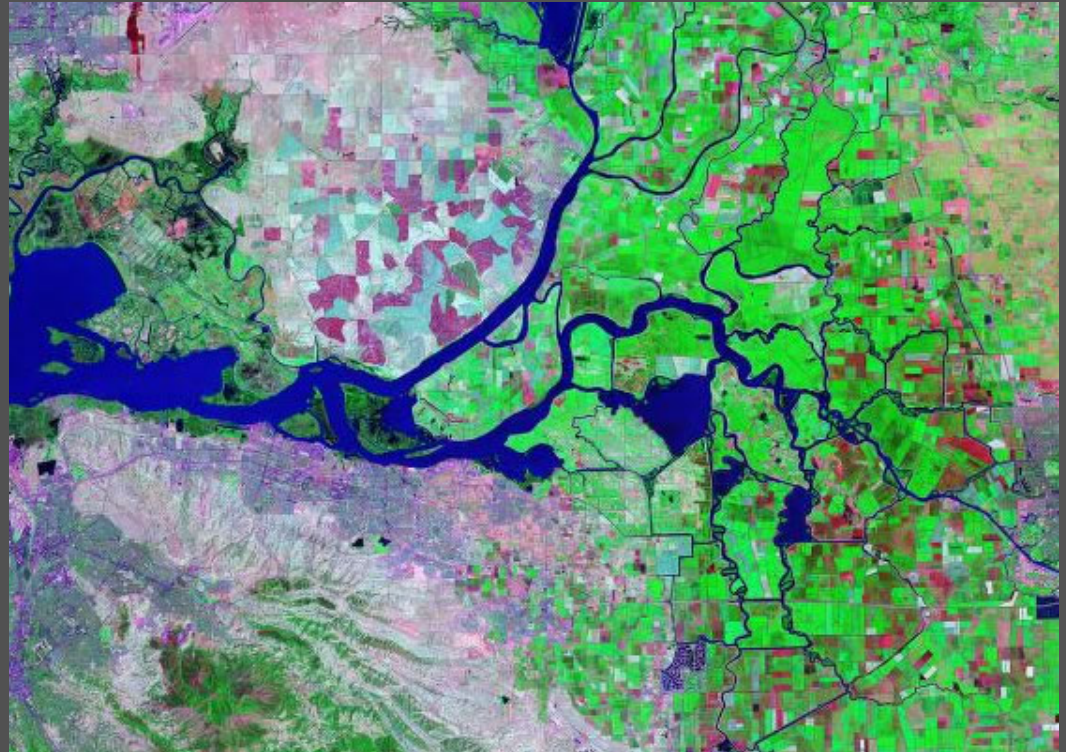
**Cathleen E. Jones, Ph.D.**

*Jet Propulsion Laboratory, California Institute of Technology*

*February 26, 2014*

# Airborne Monitoring of the Sacramento-San Joaquin Delta

## Critical Infrastructure: The Levees



- Over 60 reclaimed islands surrounded by 1100 miles of levees
- Most islands lie below mean sea level.
- Collects run-off from approximately 2/3 of the state via the Sacramento and San Joaquin rivers.
- Supplies water to ~2/3 of the residents of California and to almost all of the agriculture of the Central Valley.

THE DELTA IS THE MOST CRITICAL WATER RESOURCE IN CALIFORNIA.

# Airborne Monitoring of the Sacramento-San Joaquin Delta

## UAVSAR: NASA's Uninhabited Aerial Vehicle Synthetic Aperture Radar

### Project: Monitoring Levees and Subsidence in the Sacramento-San Joaquin Delta

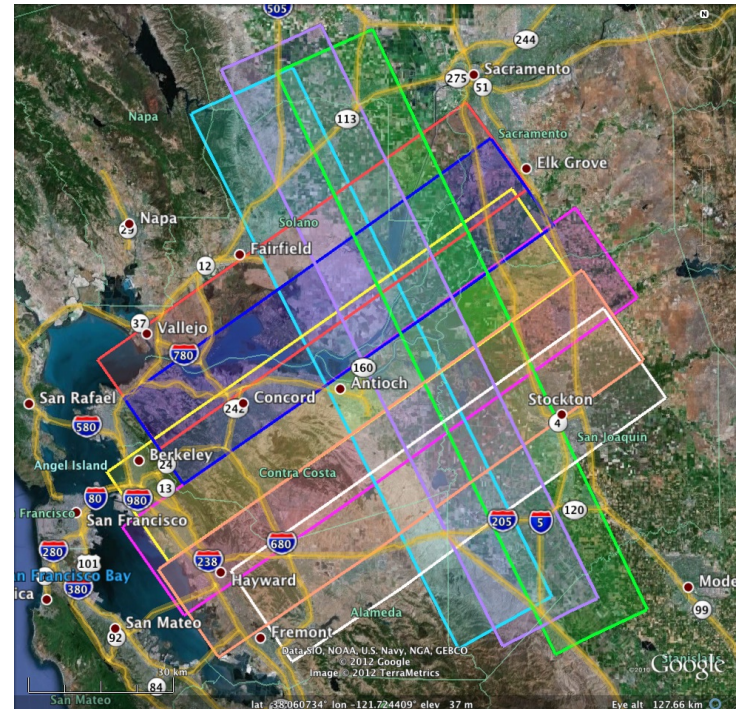
Funding Agencies: NASA Applied Sciences, Dept. of Homeland Security, *CA DWR (pending)*

Study Period: Ongoing Since July 2009

Collaborators: Joel Dudas (Ca. DWR); Dr. Gerald Bawden (USGS); Dr. Steven Deverel (HydroFocus, Inc.); Dr. Priyanka Sharma, Dr. Sang-ho Yun, Dr. Scott Hensley (JPL)



The UAVSAR L-band radar is housed in a pod flown on the NASA G-3 platform, shown here in flight over Edwards Air Force Base.

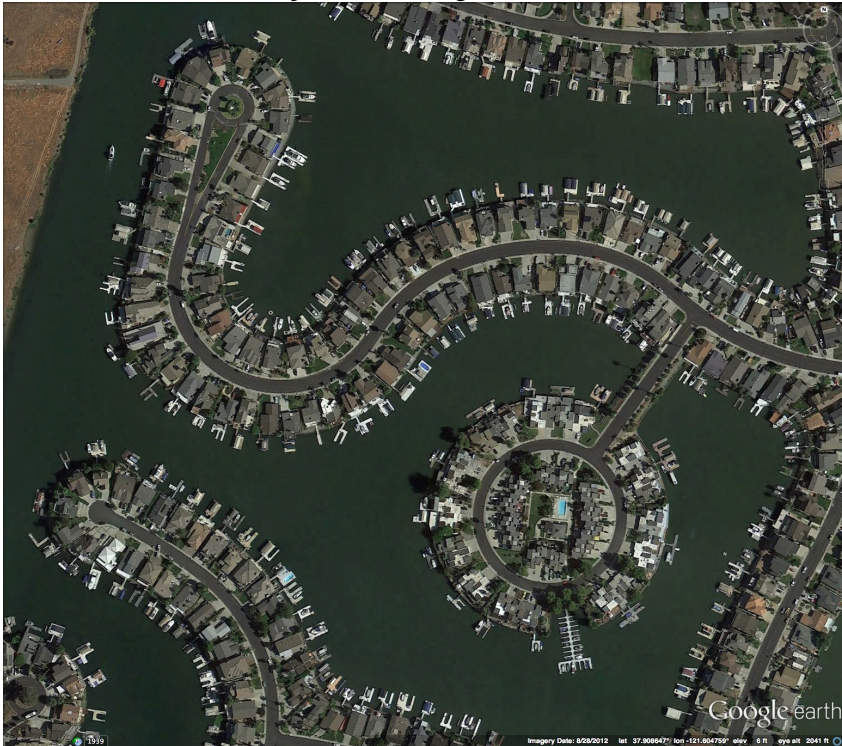


# Airborne Monitoring of the Sacramento-San Joaquin Delta

## Radar Remote Sensing

*Radar imaging  $\neq$  photogrammetry or visual surveys*

*Optical Image*



*Radar Image*



UAVSAR / 7 m resolution

*Discovery Bay, California*

# Airborne Monitoring of the Sacramento-San Joaquin Delta

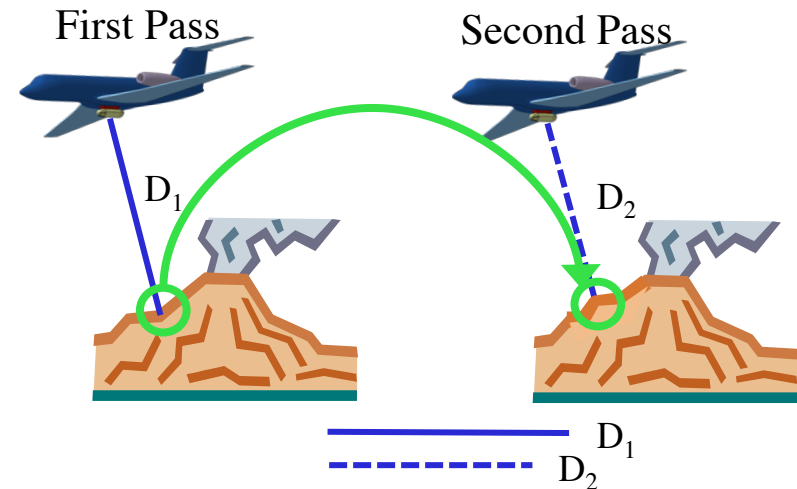
## Radar Remote Sensing

*Radar imaging ≠ photogrammetry or visual surveys*

### Microwave-band Radar can...

- 1) See through clouds, smoke, haze.
- 2) Image the surface of the Earth day or night in any light conditions.
- 3) Image large swaths of land in a short amount of time with relatively high resolution.
- 4) Determine where there is standing water.
- 5) Determine the type of surface based upon physical (orientation) and electrical characteristics.
- 6) Determine whether the surface changed properties (i.e., seep developed, equipment was moved, water level dropped)
- 7) Detect changes in hard targets that don't move a lot.
- 8) Detect very small scale (few millimeters) change in the position of hard targets.

### Differential Interferometry (DINSAR)



$$\Delta\phi = \frac{4\pi}{\lambda}(D_2 - D_1)$$

$\lambda$  = wavelength of radar

# Airborne Monitoring of the Sacramento-San Joaquin Delta

Motivation: High Resolution Radar Can Resolve The Levees



# Airborne Monitoring of the Sacramento-San Joaquin Delta

Motivation: High Resolution Radar Can Resolve The Levees



## *Risk Assessment & Disaster Management (Levees)*

- *Levee conditions – detect anomalous change*
- *Emergency response*

## *Water Resource Management (Subsidence/Levees)*

- *Short Term: Levee repair*
- *Long Term: Inform a viable water management plan.*

*InSAR can also be used to remote monitoring of the California Aqueduct & other levees in the state.*

# Airborne Monitoring of the Sacramento-San Joaquin Delta

## Levee Threats

012 05 18.indd - Levee\_Threat\_Monitoring\_Guidelines.pdf

### Levee Threat Monitoring Guidelines



*Sloughs  
&  
Slides*

State of California  
Department of Water Resources  
2012 Edition



*Cracks*



*Seepage*



*Sand Boils  
&  
Sinkholes*



*Slope Instability*

*Subsidence*

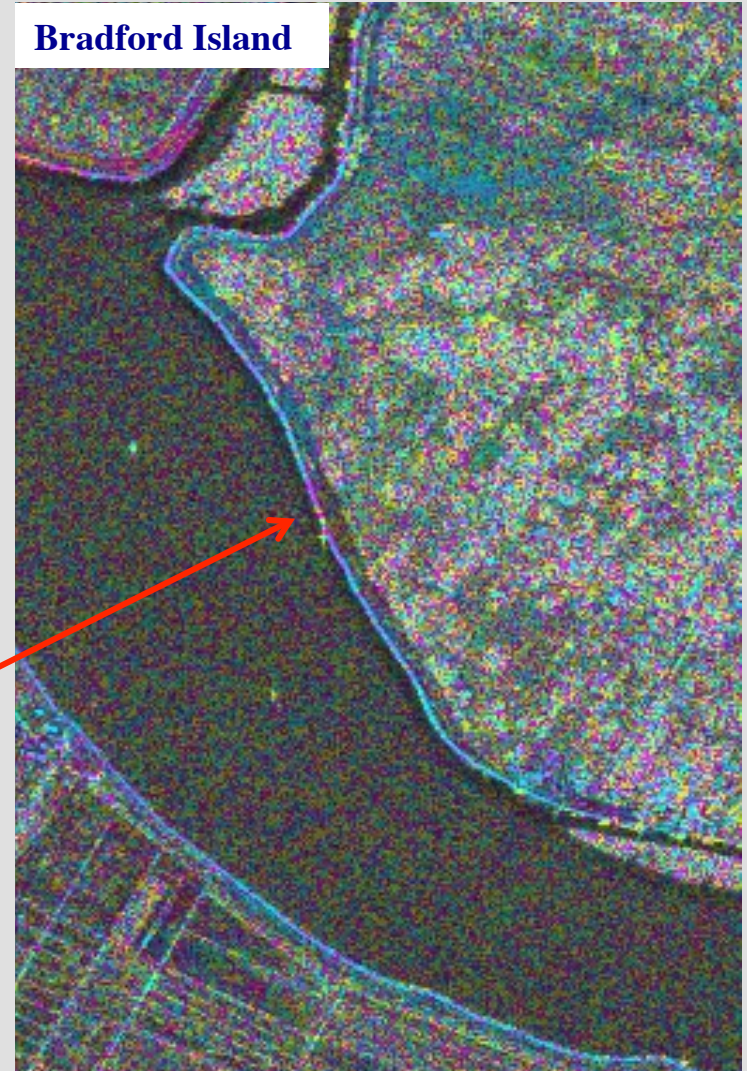
Photo credit: Tom Williams,  
Gerald Bawden, Cathleen  
Jones

# Airborne Monitoring of the Sacramento-San Joaquin Delta

## Levee Post-Repair Settling (Bradford Island)



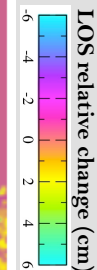
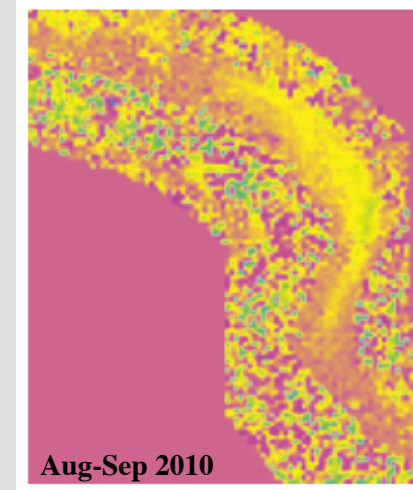
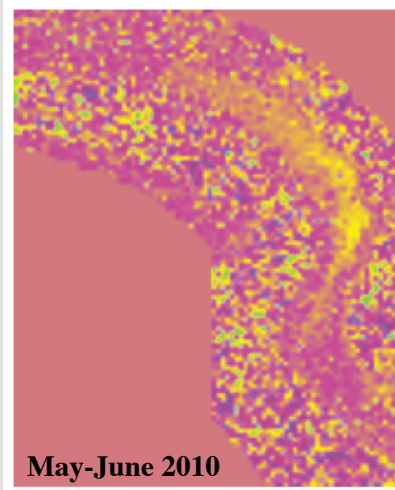
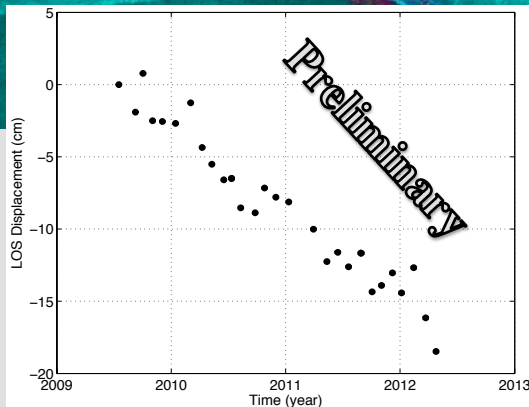
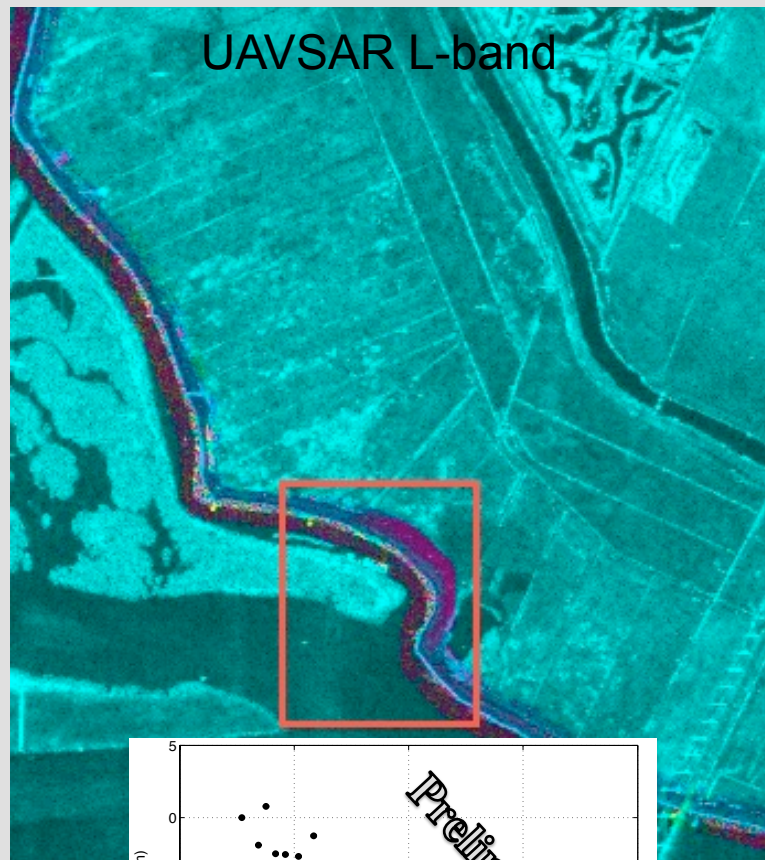
*Subsidence of  
~1" in 1<sup>st</sup> year  
along the  
repaired section  
of the levee*



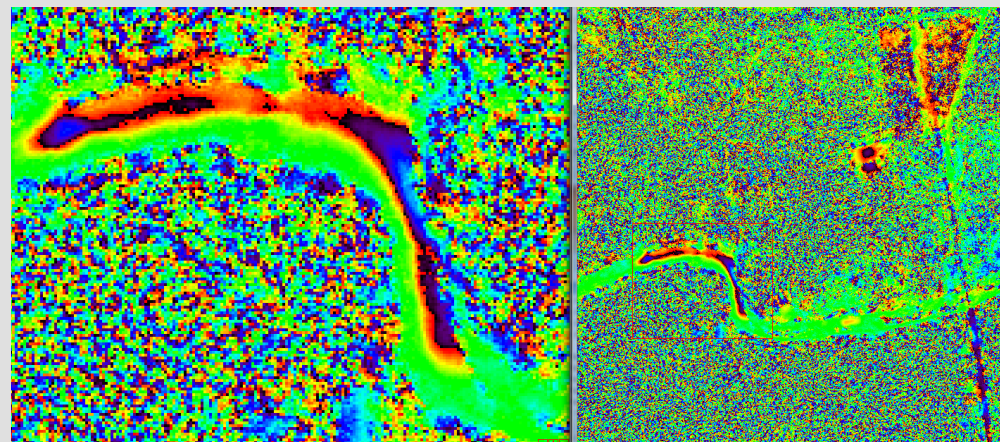
*1 year temporal baseline 7/2009 - 7/2010*

# Airborne Monitoring of the Sacramento-San Joaquin Delta

## Localized Subsidence Along Levee Toe

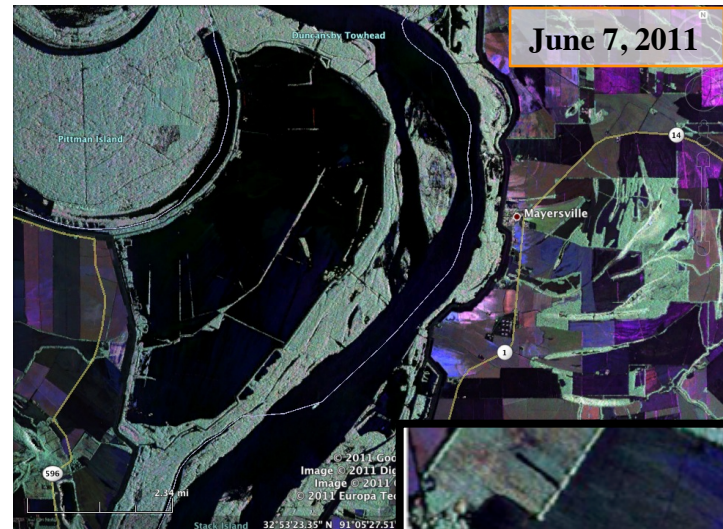
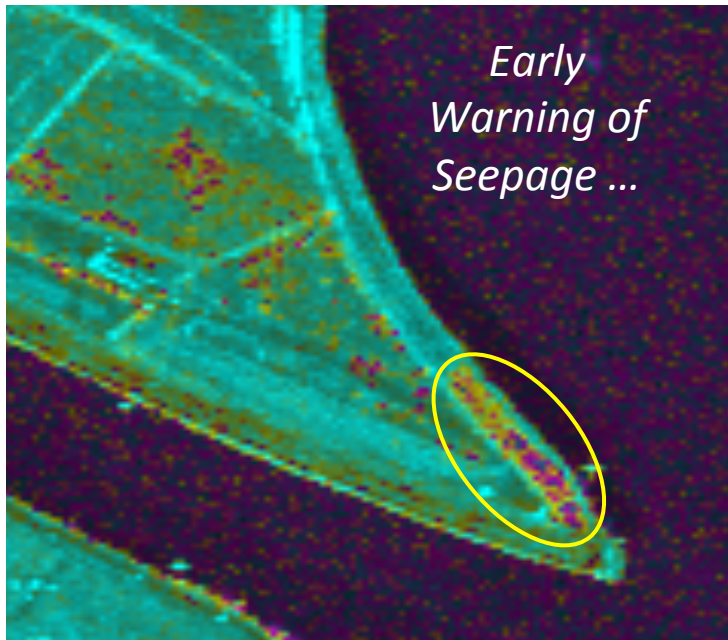


## Satellite X-band

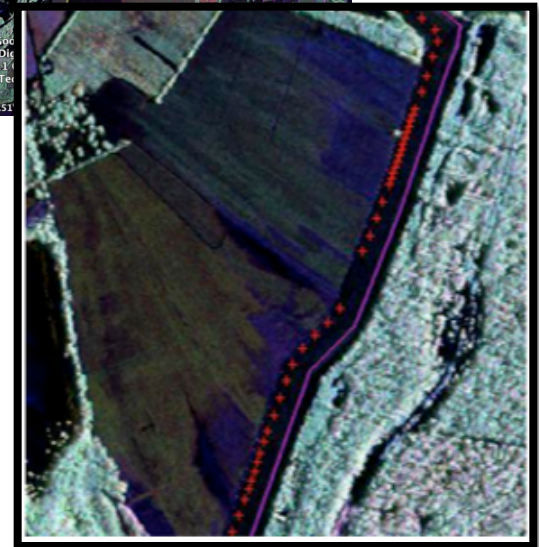


TerraSAR-X © DLR 2013

# Airborne Monitoring of the Sacramento-San Joaquin Delta Seepage



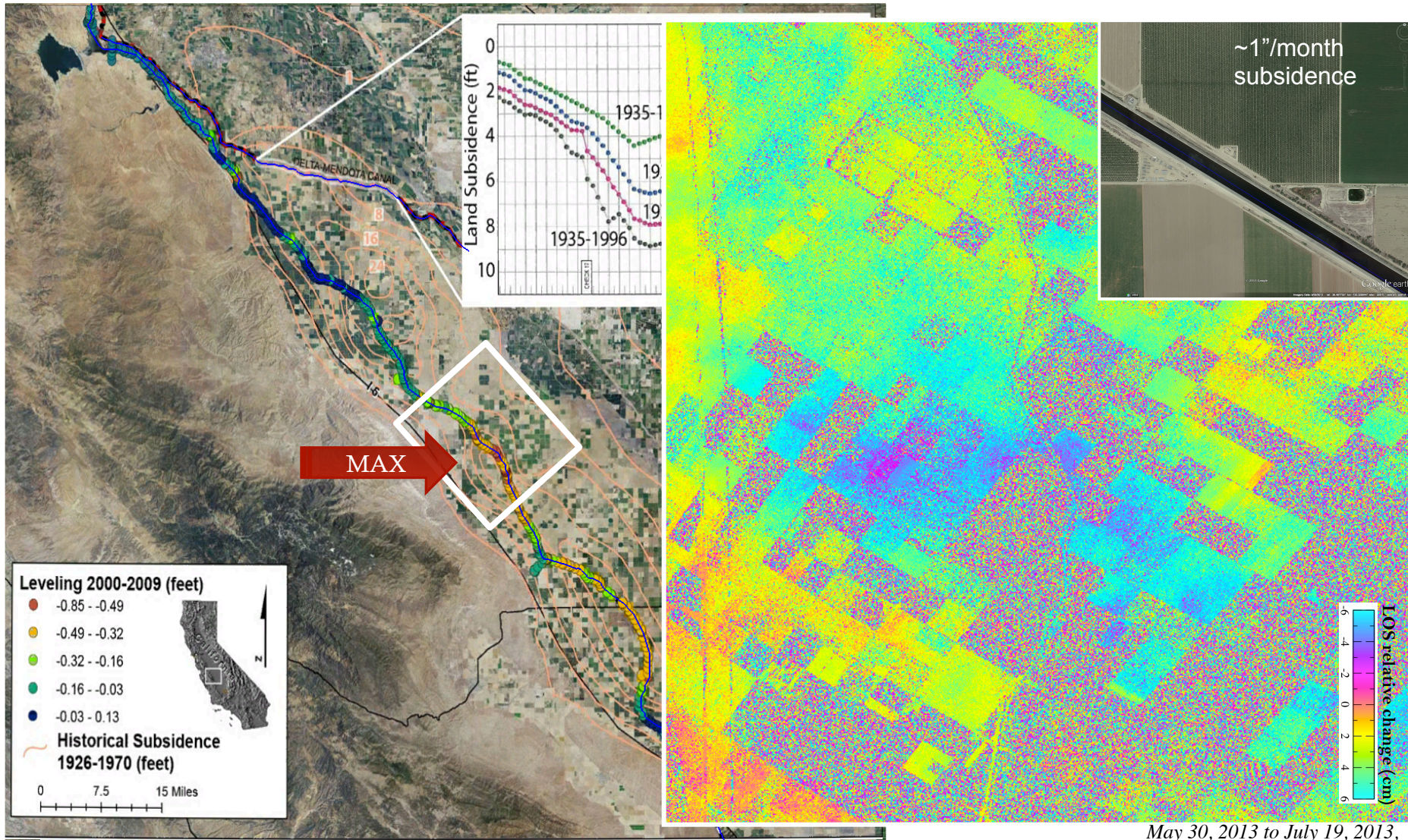
*... Emergency Response During Major Flood Events*



**These types of techniques can be used to find leaks in the California Aqueduct.**

# Airborne Monitoring of the Other Critical Infrastructure

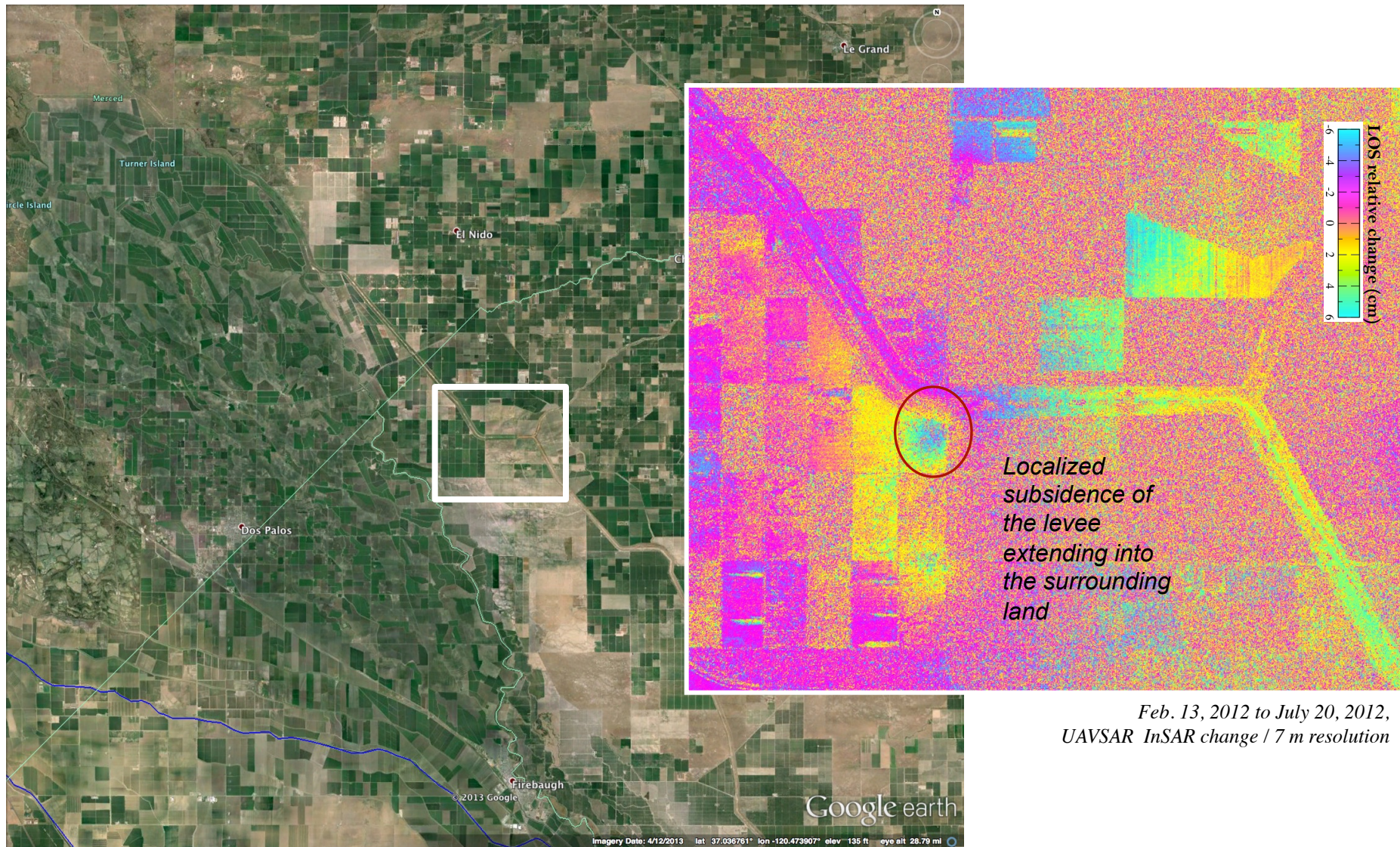
## California Aqueduct



May 30, 2013 to July 19, 2013,  
UAVSAR InSAR change / 7 m resolution

# Airborne Monitoring of the Other Critical Infrastructure

## Chowchilla Bypass Levees



# Airborne Monitoring of the Sacramento-San Joaquin Delta

## Conclusions



**Radar remote sensing provides monitoring of seepage and deformation over large areas at one time.**

**Our pilot project with NASA, Ca. DWR, and DHS to monitor levees and subsidence in the delta has established a baseline to monitor small-scale critical infrastructure for operation integrity, flood management, emergency response, and water resource management.**